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VOL. VII. ANN ARBOR, MARCH, 1891. NO. 11.

ORIGINAL ARTICLES.

PAPERS FROM THE LABORATORY OF PHYSICAL GEOGRAPHY OF HARVARD COLLEGE.*

NO. 5. PROFESSOR RUSSELL'S THEORY OF COLD WAVES.

BY S. M. BALLOU.

Read at the meeting of the New England Meteorological Society, in Boston, January 20, 1891.

Professor Russell's Theory. — In the Report of the Chief Signal Officer for 1889,† Assistant Professor Thomas Russell presents a report on forecasts of cold waves. This is a subject of more than ordinary interest to the public, both on account of its relation to everyday life, and of the great commercial and agricultural value of accurate predictions. To present the subject in a more extended form, the same author has recently published an article on "Prediction of Cold Waves from Signal Service Weather Maps."‡

In his official report, Professor Russell devotes some little

*The previous papers of the series are:

1. W. R. Dewey,—The Causes of Anticyclonic Cold in Winter. *Amer. Met. Jour.*, III, 1886, 25-32.
2. H. B. Gibson,—Water-Spouts on the Gulf Stream in Winter. *Amer. Met. Jour.*, III, 1886, 119-127.
3. W. M. Davis and C. E. Curry,—Ferrel's Convectional Theory of Tornadoes. *Amer. Met. Jour.*, VI, 1889-90, 337-349, 418-431, 448-463.
4. W. M. Davis and R. DeC. Ward,—General Account of the Land and Sea-Breezes. Investigations of the New England Meteorological Society, 1889, in *Annals Astron. Obs'y Harvard College*, XXI, pt. ii, 1890, 216-238.

† Annual Rep. Chief Signal Officer, 1889, App. 12, 145.

‡ Amer. Jour. Science, XL, December, 1890, 463.

space to the probable origin of cold waves. The theory presented is, as the article states, "somewhat opposed to the accepted theories in regard to convection currents in the air," but its author believes that the facts brought forward in confirmation will bear it out.

The topic is one of importance, for, while an understanding of the cause of such phenomena is not absolutely necessary for their successful prediction, yet a thorough knowledge of their origin would be of great assistance to their careful study and to the final solution of their movements. It would seem advisable, therefore, to note the differences between the theory now advanced and that which other meteorologists commonly hold, and to present the arguments with which the advocates of the theory generally accepted support their position.

Professor Russell's theory is briefly as follows: In the winter there must be times when the diminution of temperature upwards is greatly in excess of what it is at other seasons, principally on account of the radiation into space from the upper strata of the atmosphere. Thus there is a considerable diminution of temperature upwards, and any disturbance of the air will cause overturning and a thorough mixture of the upper and lower strata; so that the air will become of uniform temperature throughout, and the air at the surface consequently much cooler than before. Further radiation from the upper strata will cause them to contract in cooling; the air will rush in from the surrounding places, and will cause an increase of pressure at the surface of the earth. From the area of cold and high pressure developed in this way, our northwest winds bring the cold air, which we then call a cold wave.

It is to be noticed that this theory is divided into two parts, the first relating to the formation of an area of cold air in the northwest, and the second to the importation across the country of the cold air by the northwest winds, which usually follow an area of low pressure as it moves across the country, forming the cold wave proper. It is with the first part, that is, with the origin of the cold wave, that we are concerned.

Summary of the Theory.—Summarizing this first part briefly: The cause of the cold area from which the cold wave is drawn is held to be a preliminary strong upward diminution of temperature in the air, a subsequent overturning, bringing the cold air to the surface and producing uniform temperature upwards, and a further cooling aloft producing high pressure.

Objections to the Theory.—Each of these points would probably be questioned by those meteorologists who hold the theory at present generally accepted; first, the possibility of any undue cooling aloft in the regions where these high pressure areas occur, to produce the instability on which the whole subsequent process depends; second, the possibility of an overturning either bringing cold air down to the ground, or producing uniform temperature vertically; and third, the increase of pressure by the further cooling of the air aloft. These objections will now be considered in detail.

Vertical Decrease of Temperature in Winter.—The first question to be raised, then, is whether there can be any undue cooling of the upper air in winter, and consequent excessive diminution of temperature upwards, preceding the formation of the area of high pressure and cold from which our cold waves come. The first argument for it, as given, is that in winter the air is sometimes, during high pressure, warmer at the top of a mountain than at its foot; and so the average diminution of about one degree in 300 feet must be made up by a great decrease of temperature at other times.

It does not appear that this reasoning is adequate, for the occasional increase upward, or inversion of temperature, might be counterbalanced by a much longer period of slight diminution, which, however, might not amount to instability. But a more important consideration is whether the figures quoted are applicable to the case of incipient cold waves. The average diminution of 1° in 300 feet, while correctly representing the upward diminution of the temperature in that section of the country where the observations were taken, does not appear necessarily to hold true for the winter temperature of that part of the country where our cold waves originate.

As a matter of fact, the only continuous observations of upper air temperature, from which this average diminution upward can be computed, are those taken at mountain meteorological stations. There are several of these stations in different parts of the world, but they have one characteristic in common; they are all situated in or near the track of cyclonic storms, and not in regions whence cold waves flow. The temperature conditions of the air during the passage of cyclonic storms must have an appreciable effect on the average diminution of temperature; and hence this average cannot justly represent the average for a region where cyclonic storms are unusual.

Regions where Cold Waves Originate.—Our cold waves come from the great continental interiors, Manitoba and the Northwest Territory on this continent, and the cold interior of Russia and Siberia in the Eurasian continent. These regions have no regularly established high-level stations, from which their average vertical diminution of temperature can be found; and so the average diminution quoted for the world in general cannot be fairly held to represent the special conditions in these cold wave factories.

On the contrary, we shall find from other considerations, that the average diminution of temperature in these regions must be regarded as so slight that there can be no chance for spontaneous convectional overturning.

Winter Weather of Continental Interiors.—In the first place, the weather characteristics of these places are well marked. Throughout the winter they are persistently covered by continental areas of high pressure, with accompanying clear skies, dry air, little or no precipitation, light winds or calm, and low temperature. Loomis * found high-pressure areas in the continent of Eurasia, which lasted practically all winter. In the successive winters beginning 1877–78, he finds persistent anticyclonic weather for 50 days, 56 days, and 60 days. In 1882–83, there were high-pressure areas of 38 and 39 days duration, and the next winter of 29 and 22 days. The Canada Meteorological Observations show a corresponding prevalence during the winter of clear, calm, and cold weather with high pressure throughout the Northwest Territory, and to a less marked degree in Manitoba. In our country and in Western Europe, the nearest approach to these conditions is found during the prevalence of anticyclones; it is therefore to the vertical decrease of temperature of anticyclones in our country that we must look for the best indication of the diminution prevailing all winter long in continental interiors.

Vertical Decrease of Temperature in Winter Anticyclones.—Secondly, the upward diminution of temperature in the lower air during anticyclonic conditions in our country and Europe is little or nothing, the atmosphere then being in a state of extreme stability. Indeed the usual accompaniment of our anticyclones is an inversion of temperature, or increase upward, for some distance above the earth's surface. Hann † cites

* Contributions to Meteorology, New Haven. 1885, 106–111.
† Zeitschr. für Met., XI, 1876, 129.

numerous instances of this; Loomis* and others mention it.

Nor can we suppose that this inversion of temperature can be produced after the instability of the air has caused overturning. For if the conditions of radiation, etc., were such at first as to make the decrease of temperature upward more rapid, the same conditions after overturning would tend again to make instability, instead of producing the opposite result, namely an increase of temperature upwards.

So from all the evidence at hand we must conclude that the average winter condition of the atmosphere in the regions where cold waves originate is that of extreme stability, giving no opportunity for any overturning.

Radiation from the Upper Air.—Neither can the physical reasons which are brought forward to explain the instability of the air in winter be held sufficient to vitiate in any wise this conclusion. The argument presented is that: "The causes that favor a diminution of temperature upward are more active in winter than in any other season. The nights are very much longer. There is a greater amount of radiation into space from the upper strata of the atmosphere. There is also greater radiation from the lower strata. But that from the upper strata is proportionately larger. During the day in winter there is a greater relative absorption of heat from the sun's rays in the lower strata of the atmosphere than in the upper. This is due to the almost entire absence of moisture in the upper strata of the air in winter time, and possibly also to the absence of dust particles."

While at first thought it would be natural to suppose that radiation from the upper strata of air was proportionately greater than from the lower, this supposition cannot stand in face of what is known of the physical properties of gases. It is admitted that absorption in the upper air is less than in the lower; hence the supposition would be a violation of the law of physics, that a poor absorber is, in the same degree, a poor radiator.† The upper strata of the air absorb only a small fraction of solar radiation, and still less, the freer they are from water particles and dust. If in the same upper strata, radiation were greater than absorption, they would cool indefinitely.

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* Amer. Journ. Science, XX, 1880, 10.
† Deschanel: Elementary Natural Philosophy, 1889, 444.
Daniell: Principles of Physics, 2nd ed., 1885, 455.
Stewart: Elementary Physics, 2nd ed., 1871, 263.
Tyndall: Heat Considered as a Mode of Motion, 18?3, 304.

Inversions of Temperature.—There are many observations that may be quoted to show directly that at night or in winter, the cooling of the upper air is less than that of the lower air, and the greatest cooling takes place in the air close to the ground. Juhlin, in a recent memoir,* quotes a series of observations beginning with those of Pictet in 1778, and extending to the present time. These show conclusively that the tendency of radiation is to cool the lower air much more than the upper. When radiation is at its best, namely, on clear winter nights, the temperature of the air close to the ground becomes lower than that at some distance above; but if radiation is checked by cloudiness, this phenomenon is not observed.

The inversion of temperature, being commonly more easily observed in mountainous than in level districts, has been usually ascribed to the flow of cold air down the hill-sides; though radiation, from the earth and from the lower air, making the lower air colder than the upper, has always been held to be the primary cause. Undoubtedly, when the air comes from a height no greater than that of a hill-top, and when the motion is so slow that the heat due to compression is lost by conduction to the cold sides of the hill, this descent in a factor is the result. But, after the observations of Eliot† in India, this can no longer be held the only, or even the principal cause. By a set of comparisons between the temperatures of the hill stations and of plain stations, Eliot proves that "these inverse relations which are exhibited by the mountain observations are due to general conditions that prevail in plains as well as in mountain districts, and hence that similar relations may obtain much more generally and widely than is usually supposed, . . . that inversion may occur over very large plain areas, and that it has, in some cases at least, little or nothing whatever to do with air motion between hills and valleys."

Small Temperature Range in Upper Air.—All these observations of the temperature of the lower air show that the effect of radiation is greatest there. Similar observations of the upper air may be quoted to show, in conformity with the physical law of radiation, that the effect of radiation aloft is comparatively slight. This is shown by the fact that whatever the differences in the conditions of radiation between summer and winter, day

*Sur la Température nocturne de l'air à différentes hauteurs, Soc. Roy. Sci., Upsala, 1890.

†The Occasional Inversion of the Temperature Relations between the Hills and Plains of Northern India. Journ. Asiat. Soc. Bengal, LIX, P. ii, No. 1, 1890.

and night, cloudiness or clear weather, the differences of temperature in the upper air are very slight.

For example, Eliot, in his paper, gives figures to show that "in Upper India the average daily range of temperature in January is very nearly twice as great in the plains as at the adjacent hill-stations. The ratio is even greater in the Eastern Himalayas."

It may be remarked that could these high-level observations have been taken in the open air away from the controlling influence of the mountain peaks, even more striking results would have been shown.

Ferrel * to the same point says: "The diurnal changes in the open air in general are perhaps not more than about one-quarter of what they are at the earth's surface."

Hann † has carried his observations still further, comparing the temperatures in the upper air in summer with those in winter, as well as observing the diurnal range. Finding with increase of altitude a steady decrease of range of temperature, he has calculated that at a height of 8,800 metres,—a height not exceeding that of some mountains—the temperature remains essentially constant through the year.

The small diurnal range aloft is mentioned by Professor Russell in the Journal of Science article ‡ as an accepted fact; and it is difficult to reconcile it with the theory under consideration, which requires a considerable cooling of the upper air, a rise in temperature aloft following the overturning, and then a further cooling.

Thus we find that in winter time, when radiation is most active, the lower air is cooled much more than the upper. So we must conclude that the upward diminution of temperature at such seasons is very slight. Further evidence on this point may now be quoted.

No Instability Caused by Radiation in Winter.—Hann § in discussing the conditions of stability and instability in the atmosphere, states that: "A temperature diminution as rapid as ascending currents of dry air must show has been found only in summer time during fine weather, quite close to the earth's surface. . . . The diminution of temperature with elevation is

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* Report of Chief Signal Officer, 1886, 224.

† Zur Meteorologie des Sonnblickgipfels. Zft. d. Deutsch. u. Oesterr. Alpenvereins, XX, 1889, 11.

‡ Page 421.

§ Zeitschr. für Met., 1874, ix, 321: Translated by C. Abbe in Smithsonian Report, 1877, 407.

slower in winter, . . because the earth's surface exerts a cooling influence on the lower strata, and often so intense that the temperature increases upward. . . . On clear days, and in clear winter months, the diminution of temperature with the altitude is slower than during cloudy weather or precipitation."

Ferrel * says: "In comparing open air observations, as those of a balloon or a mountain peak, with those of a plain near sea-level, the rate of decrease of temperature with increase of altitude is found to be greater in summer than in winter."

All these observations, and many others that could be referred to, tend to demonstrate that there is little cooling of the clear upper air in winter, and that the cold of that season is in greater part an affair of the lower air. We must conclude therefore that these observations do not give any reason for supposing that a cooling of the upper winter air in continental interiors can ever produce a condition of instability.

That any considerable convective action or overturning can take place without instability of the atmosphere seems equally inadmissible. For first we have to consider the law of conventional motion: "The ascent of warm air will not occur when the actual decrease of temperature upwards is slower than that due to cooling by ascent; for air will not rise if the process of rising would make it colder and heavier than the air through which it would have to pass." †

Overturning without instability.—The only process usually recognized as causing overturning without instability, even to a limited degree, is the motion of the wind. We have seen that the high pressure areas of continental interiors are remarkably calm, and the cold is there before any outflow to a neighboring cyclone gives a chance for this sort of mixture.

Result of overturning and mixture.—But it is an interesting question to inquire whether any overturning or mixture, if granted, could produce the requisite cold to supply a cold wave. It was a favorite theory with the older meteorologists that the cold in winter was produced by the descent of upper cold air; and the local cooling of thunderstorms in summer was ascribed to the same cause.

Descent of air in winter not a cause of cold.—The first to question the correctness of this theory was Espy. In 1841 he investigated the laws of descending currents of air with refer-

* Report of Chief Signal Officer, 1886, 224.
† Deschanel, Elem. Treatise on Nat. Philos. 1889, 477.

ence to their dynamical warming; that is, their warming due to the work done upon them in compressing them. During a trip to Europe he presented his results to the French Academy of Sciences, and the report of that body was*: "Finally, it is proved by the investigations of Mr. Espy that we should not hereafter adduce in the mean state of the atmosphere a descending current as a cause of cold."

Hann,† in 1874, states the law emphatically: "Never in winter can it happen that masses of air descending from the upper regions to the earth's surface arrive there cooler than the air they displace."

In 1875, Loomis‡ sought a cause for the sudden fall in temperature usually accompanying a thunderstorm, as well as for the cold in winter, in a descent of upper cold air. In 1880, however, he writes as follows §: "In order to determine whether the sudden changes of temperature, sometimes experienced near the level of the sea, ever result from the sudden descent of cold air from a great height, I have made an extensive comparison of the observations at Denver and Pike's Peak." After giving several tables showing the inversion of temperature we have before noticed, he concludes, "We thus learn that during periods of severe cold at Denver the thermometer is frequently lower there than it is on Pike's Peak, and hence we must conclude that this cold did not result from the subsidence of air from the upper regions of the atmosphere. . . . . . These results do not sustain the theory which I formerly advocated, that periods of severe cold are mainly the result of cold air descending from the upper regions of the atmosphere."

Adiabatic changes of temperature in air currents.—The considerations which have led meteorologists in general to reject the possibility of the descent of the upper air, in winter, producing cold at the earth's surface, may be here reviewed.

If air ascends through the surrounding atmosphere it grows colder. This is because the pressure upon it grows less, and it expands. In expanding it does work in pushing aside the surrounding air, and in doing work it must lose some of its own heat. If descending through the atmosphere, the air is compressed, work is done upon it, and so it gains heat. This change

* Comptes Rendus, 1841, xii, p. 461.

† Zeitschr. Oes. Gesell. Met: 1874, ix. Translated by C. Abbe in Smithsonian eport. 1877, p. 411.

‡ American Journal of Science. ix, 1875, p. 12: also x. 1875. 14.

§ American Journal of Science. xx, 1880, p. 6.

of temperature being independent of the outside influences of mixture, conduction, and radiation, is called adiabatic.

It is important to notice that this adiabatic change of temperature is the effect of molecular action. Each molecule in the expanding air, in striking back the surrounding molecules, must lose some of its own motion; and as heat is the energy of molecular motion, the expanding air grows colder. So it is evident that however small the volume of ascending and descending air, or however intimately mixed with other air it may be, the law, because based upon the action of the molecule, will always hold, and, unless counteracted by other influences, the temperature will change accordingly.

This loss or gain of heat is at the rate of 1.6° F. in every 300 feet of ascent or descent.* If, at any time, the upward diminution in non-saturated air, should be at this adiabatic rate of temperature, the air would be in a state of indifferent equilibrium. If the diminution is greater than this rate the air will be unstable, if less, stable.†

Graphic illustration of adiabatic changes.—To show this clearly a diagram may be used, on which the distances upward in the air are marked upon a vertical scale OY, and the corresponding atmospheric temperatures on a horizontal scale OX (Fig. 1). The rate of decrease of temperature upward at any time would be represented by an oblique line, e. g. AB, each point of which, as P, would by its height on the vertical scale and its distance out on the temperature scale, show the temperature of the air corresponding to each height.‡

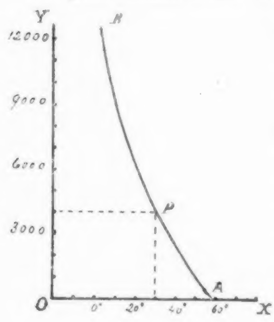

Fig. 1

By means of these diagrams, we may consider whether the ultimate effect of overturning and intimate mixture of the air would be to produce uniform temperature throughout.

Effect of mixture of upper and lower air.—The ultimate

* Hann translated by Abbe. Smithsonian Report. 1877. Report of Chief Signal Officer. 1885, Part 2. Ferrel's Recent Advances in Meteorology.

† Deschanel: Elem. Treatise on Nat. Philosophy, 1889, 477.

‡ See: W. M. Davis. Temperature Diagrams. Amer. Met. Jour. ii. 1885-86, 169. W. M. Davis and C. E. Curry. Ferrel's Convectional Theory of Tornadoes Amer. Met. Jour. vi. 1889-90, 344.

effect must be one which cannot be changed by further mixture. But if the air is of uniform temperature, as represented by the vertical line *AB* (Fig. 2), its temperature can be changed by further mixture. For if a mass of air at the earth's surface with the temperature *A*, be carried upwards, it would cool at the adiabatic rate, and at the height *c* would have the temperature *c*. Mixed with an equal mass of the surrounding air at temperature *B*, the resultant temperature would be *d*. On the other hand, bringing air down from the height and temperature *B* to the earth's surface would give it the temperature *e*, which by mixture would become *f*. So a thorough mixture of the air would produce, not a uniform temperature throughout, but warmer air below and cooler aloft; the rate of the resulting decrease of temperature being shown by a line joining *f* and *d*, and this corresponds to the adiabatic rate.

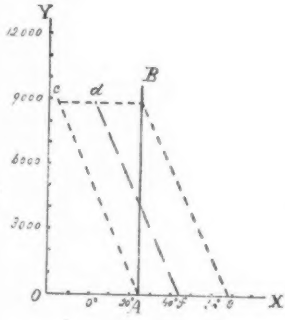

Fig. 2.

This must be, moreover, the ultimate effect of intimate mixture, for air at the temperature *f*, if raised, would be constantly of the same temperature as the surrounding atmosphere, and so mixture would not alter the temperature at any height.

The analogy of mixture in the atmosphere to that in a pail of water cannot be allowed, for water, being practically incompressible, suffers no adiabatic change of temperature in its ascent or descent through a body of water. It is this adiabatic change in air which makes the temperature resulting from mixture adiabatic instead of uniform.

Mixture of upper and lower air in winter should raise the temperature at the ground.—Moreover, it can be shown that whenever the upward diminution of temperature is less than the adiabatic rate of cooling and warming, any descent of upper air, even if accompanied by thorough mixture, must produce warming at the surface. In descending air, there can be no condensation of moisture nor liberation of latent heat, and so, however small its volume, the warming of 1.6° in 300 feet, must, except for radiation and conduction, always take place.

So if the upward diminution of temperature *a c e*, (Fig. 3), is less than this rate, each small volume of air descending and warming would reach the ground warmer than the air it enters or displaces.

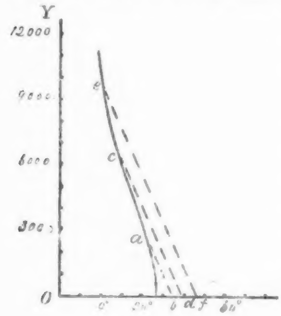

Fig. 3

This is the explanation of the heat in the fœhn or chinook in the first of its two stages; that is, when the heat is felt on the leeward side of the mountains before there is any ascending wind or any rain on the other side to liberate the latent heat which, in the second stage, is the cause of the heat.

Causes of cold in the lower air of anticyclones.—These, then, are the objections which meteorologists in general find to the theory that the cold which is the origin of a cold wave is due to the sudden descent of upper cold air. Nevertheless, in these areas of high pressure, the inflowing clouds at the top, their dissolution in the clear, calm air, and the gentle outflow of air at the bottom, all indicate a certain downward movement of the air. But it is evident that the cold must be in spite of the descent and not on account of it.

Let us examine the causes which tend to produce cold; then, by comparison with the tendency to warming due to compression, we may judge whether the cold of an anticyclone can be explained in accordance with the principles already stated.

To produce cold we have first the faint radiation in the upper air; second, the more active radiation from the lower air; and third, the influence of the earth's surface on the temperature of the lower air.

We have shown that the effect of radiation from the upper air is very slight, as the upper air is a bad absorber and therefore a bad radiator. The lower air, being denser and having a certain amount of dust and water particles in it, is somewhat better in both these respects. But it is generally recognized that the influence of the earth's surface is the most important in determining the temperature of the air.

Radiation and conduction to the earth's surface.—In the summer time it is the air next to the earth that becomes the most

heated, and a convective circulation is produced. In the winter time, and especially in the continental interiors whose conditions we are studying, the effect is reversed.

The earth's surface, being a good absorber and radiator, loses during the long winter nights of high latitudes a great part of the heat it has received during the summer, and is frozen hard. The air lying next to the chilled earth loses its heat by conduction to the earth, as well as by radiation in all directions. This loss of heat by conduction is more important than is usually supposed. Air, as it is generally stated, is a poor conductor of heat, but as it is a light gas and of very low specific heat, the loss of a very little heat will cause a great change in temperature. So while air can lose by conduction 20,000 times less heat than copper and 3,360 times less heat than iron, yet in its ability to change its own temperature by conduction, it ranks between those two metals.*

These being the causes which tend to produce the cold in an anticyclone, we must next consider the question whether they are sufficient to counteract the heat due to compression, and so to produce the cold which is characteristic of these regions.

This depends, to a great degree, on the time during which they act as compared to the rapidity with which the warming by compression is produced. If, as in the first stage of a chinook in winter, the cold air of the mountain passes is drawn suddenly down to the earth's surface, the warming is very apparent. But in an anticyclone this is far different. The air is settling at an almost imperceptible rate, and so when near the earth, has plenty of time to lose, by conduction and radiation, the heat due to its compression.

A fact which seems to confirm this theory is the observation that, during the severe cold of a calm anticyclone, a breeze springing up is sensibly warmer than the calm air. Hann first noticed this near Vienna, and it has lately been reported verbally from Manitoba. The effect of the breeze is to expedite the descent of the air and thus give less time for conduction to act.

Abnormal warmth of anticyclonic air above the earth's surface.—But as it is only near the earth that the causes which produce cold act to any great extent, it might be expected that at a short

* Maxwell's Theory of Heat, 1885, 333. A fuller statement of this distinction between loss of heat by conduction and loss of temperature may be found in Deschanel's Elem. Treat. on Nat. Phil., 1889, 413, in the *Encyclopedia Brittanica*, 9th Ed. Art. "Heat." and Amer. Met. Jour., iii, 1886-87, 497.

distance above the earth the heat of compression would be perceptible. This is precisely what occurs. The increase of temperature with altitude which is the usual accompaniment of an anticyclone is not due to the cooling of the lower air alone, but, as first shown by Hann, is the result also of a higher temperature aloft which is distinctly abnormal.

Summary by Blanford. — Here is Blanford's summary of Hann's work on this point:*

"Dr. Hann, as long ago as 1875 in a paper published in the Vienna Zeitschrift (vol. x, page 201) showed that as a result both of theory and observation, the cold that prevails in a region of high barometer in winter is really due to terrestrial radiation under the clear skies that are characteristic of such an area, that it is restricted to a stratum of very moderate thickness, and that above this, the compression of the sinking atmosphere must induce a high temperature."

This is held to be the true theory of the cause of the cold air in the anticyclone area from which our cold waves flow, and is, in general, the theory commonly accepted by meteorologists. For its statement in a less technical form a description may be quoted from Gen. A. W. Greeley.†

General Greeley on cold waves.—"The greater part of the anticyclones which cause cold waves — probably ninety per centum—are outpours of dry air, chilled to a very low temperature by radiation over the barren grounds of British America. Without doubt, the very low temperature to which the air falls is due to the barren, treeless character of that country, which is covered by scanty vegetation during summer and free from ice and snow during the winter, so that the radiation from the bare ground proceeds with great rapidity during the long winter nights in this sub-arctic region." SIDNEY M. BALLOU.

Harvard College: Class of 1893. January, 1891.

"Investigations of the New England Meteorological Society for the year 1889." Quarto, one hundred and sixty-eight pages, fourteen plates. Reprinted from the *Annals of the Astronomical Observatory of Harvard College*, Vol. XXI. It contains the observations of the society, a study of the sea-breeze by Messrs. Davis, Schultz and Ward, and an article by Professor Upton on the "Characteristics of the New England Climate."

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* "Nature," Nov. 6, 1890, 15.
† American Weather. 214.

TEMPERATURE IN HIGH AND LOW AREAS.

A summary of the essay which Dr. Julius Hann read before the Vienna Academy of Sciences, last April, on "The High Pressure Area of November, 1889, in Central Europe, together with remarks upon Barometric Maxima in General." has appeared in the JOURNAL already, (December number). A similar abstract, prepared by Prof. Wm. Davis, for "Science" last spring, drew out from Prof. H. Allen Hazen a criticism of the eminent Austrian's ideas, to which in turn Dr. Hann replies at considerable length in the *Meteorologische Zeitschrift* for September, 1890. The substance of that reply is given herewith.

In the original paper Dr. Hann expressed the opinion that "the temperature conditions of moving cyclones and anticyclones cannot well be the inherent cause (or force) of the same, but that on the contrary the motion-systems of the air afford the chief explanation of the temperature phenomena." And this conclusion was drawn from facts tending to show that the mass of air in a cyclone, above a certain low level, is cooler than that in the body of an anticyclone above a similar level. It was asserted by Prof. Hazen that this latter proposition was in conflict with elaborate computations of the increased heat in storms, made by Dr. Hann himself, and to be found in the Austrian "Meteorologische Zeitschrift" (1874, p. 321.)* Dr. Hann, in reply, first observes that "the condensation of vapor does not warm the ascending air in an absolute sense, but can only lessen the cooling from expansion with ascent. He next denies with emphasis that the "Zeitschrift" article of 1874 contains a word to the effect that the temperature in an anticyclone must be lower than in a cyclone. He then says:

"I will now show that the theory of temperature-decrease with elevation in ascending moist air currents (at a less rate than in dry air), as it was evolved in the article of mine quoted ('Zeitschrift,' 1874), does not antagonize my opinion briefly developed from the observations at the highest peak-stations, that the air volume in an anticyclone can have a higher temperature than—and on the hypothesis of a complete vertical circulation such as Ferrel assumes, it must have as much as—that in a simultaneously existing, adjacent cyclone.

* This valuable paper, dealing mainly with the effects of vapor upon the rate of temperature decrease with ascending currents, was translated by Professor Cleveland Abbe, and is to be found in the Smithsonian Report for 1878, pp. 397-417.

"Let us suppose, for instance, that the air mass in a cyclone, at an elevation of 500 m. where we will allow the condensation to begin, has a temperature of 10° C. (50° F.) This comes fairly near the real situation in the warmer cyclones of our winters. Let us now estimate the temperature which directly ascending air in the center of the cyclone will have at various heights. I use for this calculation the table on page 328 of the article cited. ('Zeitschrift,' 1874.)

"With 10° C., saturated air will cool to the freezing point after an ascent of 1820 m. in relative height, or 2300 m. absolutely: the table gives for the lower level a rate of temperature-decrease of 0.°53 per 100 m., and of 0.°57 for the upper, an average of 0.°55 for the first stage. We seek next the temperature at 3100 m. (the height of the Sonnblick), and we find for the upper level (3000 m. and—5°) an average temperature decrease of 0.°59. The temperature at 3100 m. (800 m. higher than our last calculation) is therefore—4.7. Let us compute in like manner the temperature at 4800 m. (Mont Blanc's elevation) and 7400 m. We thus get —15°.6 and —36°.4 C., respectively. The temperature-decrease per 100 m. for —15° and 5000 m. is about 0.°70; with —35° and 7400 m., 0°.9. Since the vapor tension at —36° can show a maximum of only 0.2 mm., the condensation process at this height is too nearly suspended to show. We have thus the following temperature-distribution in the ascending air current, or the center of the cyclone, whose temperature at 500 m., where the condensation has begun, was 10°.:

Height	500	1000	2000	2300	3000	3100	4000	4800	7400
			Mt. Washington.			Sonnblick.		Mt. Blanc.	Cirrus.
Temp.......	.10	7.3	1.7	0	—4.0	—4.6	—10.2	—15.6	—36.4
Dt : dh...	0.53	—	—	0.57	—	0.61	—	0.70	·0.90
	Low Area of Oct. 1, 1889.								
Temp.......	7.9	5.1	—0.6	—2.3	—6.2	—6.8	—11.9	—	—
	The same Temp. arranged about 370 m. lower.								
Temp.......	10.0	7.2	1.5	—0.2	—4.1	—4.7	—9.8	—	—

"The temperature difference between our supposed air current and the air in the actual low area of Oct. 1, 1889, shows at all levels a constant of about 2°; so that one needs to bring the temperature schedule only about 370 m. downward in order to obtain an almost perfect conformity. While we know not at what height the condensation began (Oct. 1, 1889), and though the lower air-layers became cooled greatly from the rain and snow falling from a greater height, yet no other explanation

adapts itself to this comparison than the self-evident demonstration: that one cannot discredit the estimates as a trustworthy illustration of the vertical temperature distribution in the rain region of low areas. When one considers that under similar meteorological conditions Barral and Bixio, on July 27, 1850, from a balloon at a height as great as 7016 m. observed a temperature of —39° C. (at the earth's surface, simultaneously, 17°.8), one may regard the computed temperature of —36° at 7400 m. for a winter cyclone not unreasonably low.

"If one assumes an ascending movement of saturated air in a large area, so that the temperature variation depends only on the expansion of the same and the condensation of vapor, he can hardly tell the estimated temperatures from those taken from Nature herself. The overhanging cloud-shield almost wholly precludes heating through insolation and also heat radiation. Only the cooling of the lower layers from condensation-product descending from higher layers enters into consideration. In many low areas this must depress the temperature sensibly. The foregoing little table is instructive for those who talk about high temperatures in the body of an ascending moist current, which temperatures shall then accomplish great things. Even in the center of a tropical cyclone, in spite of the very copious condensation, the probable temperature excess above the surrounding air, even at the greatest height, is not so important as one might suppose without careful computation. Let us, for instance, take a mean temperature of 28° C. (82° F.) and a relative humidity of 80 per cent., and let this air-mass in the center of a cyclone rise; then one would get the following practically correct temperatures for these respective layers. At the earth's surface under our supposition the vapor tension is 22.5 mm. (a water content of 21.6 gr. for each cubic meter). The condensation, in view of the expansion of the air, and the thereby increasing relative humidity, sets in at about 500 m. above sea-level. From the condensation level upwards the heat decrease for every 100 m., up to 2000 m., is practically constant at 0°.42; between 2000 and 3000 m., about 0°.44; between 3000 and 4000 m., 0°.45; and beyond about 5000 m., 0°.46. Thence we compute the following:

Height	0	500	2000	3000	4000	5800
Temp.	28	23	17	12.5	8	0

"The mean temperature at 2000 m. in Ceylon (Mt. Newera Eliya) is for the year, 14½° C. (58°.1 F.); in May, 16 (61° F.); at

3000 m. (Dodabetta peak), for the year, 10°; for May, over 12°; at 4000 m., about $5\frac{1}{2}°$ or $6\frac{1}{2}°$, according to observations on Antisana (Andes).* One finds from this that in a tropical cyclone, under the most favorable assumption, the temperature of the ascending air mass is perhaps 2° C. above the average temperature of the surrounding air-layers; which gives a rising tendency, to be sure, but one very different from the established ideas on this subject, which are the basis of many theories. Here, too, in fact, the lower layers of the air-mass in the cyclone were sensibly cooled by the abundant rainfall from the upper ones.

"The temperature in an adjacent anticyclone, existing simultaneously with a cyclone, cannot unfortunately be estimated. Though we know not the original temperature of the air-masses descending there, nor the heat radiation at great heights, yet the temperature of these masses will be considerably lowered (by radiation before descent); for certainly the air in the body of an anticyclone is dry and the sky clear. But this much is evident: with the assumption of a complete vertical circulation one must count on a very high temperature where the descending air warms up about 1° C. for every 100 m.

"Were the air in our already supposed winter cyclone, having been cooled at 7400 m. to about $-36\frac{1}{2}°$, able to descend directly and quickly to the earth, it would there acquire a temperature of $37\frac{1}{2}°$. But the conditions for such an operation are not afforded in Nature, and therefore so steep a temperature-gradient is not attained. On the other hand, it would not surprise us if the observations in the center of an anticyclone, where the air has already slowly descended, showed 0° and over at 3000 m., while in the cyclone at the same height the temperature would be below $-4\frac{1}{2}°$.

"Thus the theory (that the liberation of latent heat by condensation of vapor lessens the rate of temperature-decrease in ascending air currents) is not in conflict with the facts communicated by me in my introduction to the essay cited. On the contrary, the harmony is surprisingly great. The idea

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* Without giving it too great value as evidence, Dr. Hann here describes in a foot note a cyclone observed by Sykes, April 14-19, 1847, from Dodabetta peak (8640 feet up), Ceylon. Barometer readings, wind force and rainfall are given in detail for several days to show its genuineness. The center appears to have come, at no time, nearer than 166 English miles to the observatory, on its way up the Malabar coast. The daily mean temperatures were, beginning with the 14th meridian: 11.2 C., 11.1, 9.2, 10.4, 11.2 and 11 5. Dr Hann observes: "The temperature remained about 3° C. below the monthly mean during the passage of the cyclone, and was higher both before and after this." The wind directions were: 14. E. by N.; 15, E.: 16, E. by S.; 17. SE. by E., S., W., NW., and then back to S.; 18, S. by W.

enunciated by me that in a perfect vertical circulation the descending current must have a higher mean temperature than the ascending, proves to be in full accord with the theory and the recent observations at the peak-stations. But it is clear that the temperature conditions here exhibited, which are a necessary physical consequence of the vertical motion of the air, must operate against a continuance of the once established vertical circulation."

The utility of Alpine observations, 2000 miles from the main track of storms and 1500 miles from the nearly permanent winter high area of Siberia, as a key to the vertical temperature distribution in the centers of moving high and low pressure areas, having been questioned, Dr. Hann replies:

"One must study the phenomena of Nature where the chance is provided. In the main track of cyclones over the Atlantic ocean it would be impossible ever to observe temperature at a great height. The chance of observing the vertical temperature distribution in the inner part of a cyclone is in the Alps unfortunately most rare. The low area of Oct. 1, 1889, examined by me in this discussion, was, to be sure, no 'storm,' but yet a well-defined area of low pressure whose center, with a pressure of about 752 mm. (29.61 in.) at sea-level, lay over the Eastern Alps. The winds over Central and Southern Europe circled about this minimum; on the mountain peaks either calms or feeble winds prevailed, an evidence that it was in the central area of low pressure. * * * Every unprejudiced person will further concede that those observations which show that with the passage of a low area at a distance, whether on the north or the south, the temperature sinks, right on high Alpine peaks immersed in the condensation area, certainly permit a conclusion that the area of low barometer can scarcely be the seat of a relatively high temperature, but the reverse is clearly the probability.

"The stations on Alpine peaks afford a specially good chance, on the other hand, for examining the vertical arrangement of temperatures in high areas; for over the Alpine region in winter high areas of great intensity and long duration often lie.* It is simply absurd to attack the pertinence of these observations. The evidence of high temperatures in high areas, up to 3000-

* It is pointed out in a foot-note that the Alps have this advantage over Pike's Peak and Mt. Washington: By having stations at various elevations intermediate between the highest and lowest more copious and more accurate data are obtainable for computing the mean temperature of the body of air in an anticyclone.

4000 m., belongs to the best assured results of modern meteorological research.*

Professor Hazen had offered this objection also: "It would be a great mistake to study simply a rise or fall of pressure on a mountain as the passage of a storm or high area. One of the greatest falls of pressure on Pic du Midi in France accompanied a high area, and was caused by the intense cold. This single fact is sufficient to disprove all these fine-spun theories of Dr. Hann."

The Doctor points out that he himself carefully noted in 1879 (*Zeitschrift*, p. 154) that pressure variation on high mountains with the passage of low areas is in part an effect of temperature variation. But replying to Marc Dechevrens† (*Zeitschrift*, 1888, p. 10), he insisted, nevertheless, that such observations had some value as evidence of high or low areas. In that connection he furnished new estimates of the temperatures on mountain-tops, corresponding to air-pressure at sea-level; and in preparing his essay of April, 1890, he studied the high and low areas discussed therein with this in view. No date was given by Professor Hazen for the instance cited by him; and Dr. Hann, after careful search, disputes the accuracy of the statement. He says: "No doubt Professor Hazen had in mind the low area of March, 1883, which was the lowest one in the collection of observations on the Pic du Midi accessible to me, and was attended with the lowest temperature (—29° C.) which has hitherto been observed there." And in order to show that there was low pressure at the base of the mountain as well as at the summit, and that therefore the low area observed at the top was not an effect of the sinking of the air through cold and increased density, the Doctor presents the following table, for which the data are taken from the records of the French Central Weather Bureau for 1883.‡

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*Reference is made to an observation of 8° rise in temperature with an ascent of 1000 meters, in a balloon from Berlin, Dec. 19, 1888. This was observed between 1 and 4 p. m., and was in an anticyclone.

†The claims, made by Dechevrens, of priority in announcing that on high mountains the temperature is low in cyclones, is disputed by Dr. Hann.

‡Other details which Dr. Hann has collated may be thus briefly summed up: During the last ten days of February there was a high area of about 775 or 780 mm. (30.51 —30.81 in.) over Central and Western Europe, with which, it will be seen, there was high temperature on the Pic du Midi. For several days beginning with March 1, the pressure continued moderately high over Northern Europe, with no great depressions visible; but on March 6, with the high area centered over Northwestern England, two storms developed one over Scandinavia and reaching to the Adriatic, and the other over the western Mediterranean, near Lyons and Genoa. The latter became more intense on the 8th (Southern Hungary, 29.33 in.). On the 9th a third storm lay on the Southern coast of

In this connection, Dr. Hann has examined the temperature maxima, eleven in number, of the winters of 1881–2, 1882–3 and

1883	Pic du Midi: 2859 m.					Toulouse: 194 m.		
	Bar.	Temp.		Wind.	Cloudiness.	Bar.	Temp.	
	7 A. M.	7 A. M.	Noon.			6 A. M.	6 A. M	Noon.
Feb. 19	534.3	—11.2	—10.0	NE. 1	10	748.4	5.3	7.6
20	32.9	—14.0	—11.0	NE. 1-2	1	53.9	2.6	8.8
21	44.3	—7.4	—2.1	NE. 1-2	0	61.1	0.6	9.0
22	46.7	—3.0	1.4	ENE. 1	0	59.6	0.3	9.9
23	50.1	—3.2	0.0	ENE. 2-3	1	62.3	3 4	12.1
24	50.6	—2.6	3.5	ENE. 1	1	61.8	3.8	8.3
25	48.8	—2.1	0.4	ENE. 2	1	58.4	2.7	10.5
26	47.1	—3.5	1.4	NE. 1	1	56.7	4.6	12.3
27	45.6	—4.3	—0.4	ENE. 1-2	1.5	56.4	4.1	6.6
28	45.7	—3.0	—0.5	ENE. 1	1	56.1	2.6	9.0
March 1	43.1	—5.6	0.5	ENE. 1	1	55.3	4.7	10.6
2	40.5	—4.0	0.6	ENE. 1	1	50.5	4.3	10.7
3	39.0	—6.0	3.2	ENE. 1	1	50.1	4.7	10.6
4	35.4	—13.8	8.4	ENE. SW. 2	5	50.8	4.3	10.7
5	36.7	—15.0	10.3	E. 2	3	52.9	3.3	8.2
6	37.3	—9.7	—5.0	NE. 2 NW. 2-3	1	51.2	—0.6	8.5
7	24.7	—21.0	—18.0	NE. 3. NW. 3	10	41.7	—1.3	9.0
8	20.9	—20.0	—15.0	NW. 2-4	10	35.1	0.6	9.0
9	18.8	—21.0	—17.0	Var.	9	34.3	—1.7	2.8
10	17.3	—24.5	—21.5	NW. 2-4	10	33.4	—0.8	2.3
11	21.3	—21.2	—19.3	NNW. 2-4	10	37.1	—3.2	—1.4
12	25.8	—16.6	—14.0	NW. 3-4	10	39.8	—3.7	—1.5
13	29.5	—14.4	—9.0	Var.	0	47.3	—4.2	1.9
14	31.9	—14.0	—13.0	NW. 2-3	1	47.9	—1.4	4.8

1883–4, and he finds that when these occurred on the Pic du Midi there was an area of high pressure over Europe in which the Pic was included. Scrutiny of the details furnished by him show that it mattered little, apparently, whether the center of the area lay to the north or the south of the Pic.* These obser-

France 29.53 in.), which grew more severe on the next day. (Gulf of Lyons. 29.33), The Pic du Midi (Pyrenees) then lay on isobar 752 mm. (29.61 in.), on the western side of the depression. Northwesterly gales, severe cold and snows prevailed in Southern France and even in Sardinia and Corsica. This storm moved over Italy and the Balkan peninsula March 10-11, with increasing intensity (29.33 in.), and on the 12th this or another storm over the Baltic showed a reading of 29.13 in. Pressure rose over western Europe March 12-13, a high area coming into Spain and France from the southwest.

* Later in this article, referring to the famous anticyclone of Nov. 12-24, 1889, Dr. Hann says the temperature was lower both before and after it than immediately during its prevalence in the Alps. "This high," he adds, "produced generally up to 3100 m. above the sea, a warmth which was not again observed until past the middle of May, 1890, despite the fact that in the latter part of March, in April and in May unusual warmth prevailed in the lower layers."

vations represent conditions at the summit (2859 m. or 9380 feet). The following figures are also introduced in order to exhibit a rise of temperature with high pressure at Plantade station (2366 m. or 7762 feet) on the Pic, a little lower down:

1878 Jan.	Plantade.				Toulouse.		
	Bar.	Temp.		Rel. Hum.	Bar.	Temp.	
	7 A. M.	7 A. M.	Noon.		7 A. M.	7 A. M.	Noon.
10	565.2	—17.1	— 8.2	41	748.2	—0.5	—1.5
11	67.2	—16.0	—13.0	82	51.1	—2.5	—0.3
12	67.2	—21.0	—16.0	60	54.7	—7.4	—5.9
13	73.5	—16.0	8.4	32	61.2	—8.4	—4.3
14	79.5	— 9.2	2.5	23	63.6	—4.0	1.4
15	80.0	— 4.0	1.0	47	60.8	—2.6	2.9
16	78.5	— 0.8	5.0	17	58.5	1.6	6.5
17	78.0	— 1.2	3.1	32	57.1	3.2	5.7
18	75.4	— 5.1	3.0	14	55.3	3.8	5.3
19	74.8	— 7.6	1.2	18	54.8	1.8	5.8
20	77.1	— 8.2	1.0	22	57.4	—0.4	4.8
21	80.3	— 1.4	8.8	22	60.5	2.0	5.3
22	82.2	4.0	6.2	42	58.9	—1.6	6.8
23	78.3	— 0.4	1.8	44	55.9	1.2	8.9
24	72.4	— 8.8	— 6.8	100	50.3	6.8	8.8
25	64 3	— 5.8	— 4.7	100	38.1	8.0	9.5
26	64.0	—14.4	—11.1	100	42.8	2.6	5.8

Low areas passing near the Pic du Midi were also examined. Such instances are scarce, though more frequent than those of cyclones moving near the Alps. Four cases are described, all occurring in the winter (1881–2, 1882–3, or 1883–4), the centers being over the Bay of Biscay, the western Mediterranean, Northern France, the Irish coast or the English Channel, and the Pic lying far enough within the borders to have a pressure (reduced to sea-level) of from 745 to 757 mm. (29.33 to 29.80 in.). The mean temperature for the twelve days covered by these storms was —10°.4 C. For the eighteen days embraced in the eleven high areas already mentioned the mean temperature was 1°.4. Dr. Hann says:

"The temperature on the Pic du Midi under the influence of a neighboring low center is never so high as under that of a high. Usually it is both low and below the monthly mean in the former case * * * The mean temperature departure for all the near-passing lows was about —2.0 (—3°.6 F.). This much,

then, is clearly established for the Pic du Midi: that the temperature there, at an elevation of about 3,000 meters, within the scope of low areas is sensibly lower than when in the range of highs.

"But the lowest temperatures on the Pic du Midi set in, ordinarily, not with the low center itself, but when the low has passed on the south side. The Pic thus stands between a high area on the north and a low area on the south. As I have shown for the Sonnblick, usually the lowest temperature in winter occurs here with an average barometric reading at the sea-level.* The observations on the Sonnblick and on the Säntis, as on the Pic, show that the severest cold commonly occurs toward the close of winter, when a low center lies over the Mediterranean and Adriatic; generally high pressure to the west and low to the east thus produce widespread, high north winds * *

"This brings us to the third point of Professor Hazen's objection, who thus sums up the results of his investigations of temperature on Mt. Washington † with the passage of highs and lows: "When a storm approaches within 500 or 600 miles of this almost perpendicular and isolated height, the temperature begins to rise; and when the center passes, the average temperature of its central core is more than 10° F. higher than that of the air 500 miles in advance. As the storm passes off, the temperature rapidly falls, and is 15° F. lower 500 miles after it than at the center. When a high area passes, the temperature begins falling, and the diminution and subsequent rise follow each other in almost exactly the manner and to the degree of the reverse operation in a storm."

"What Mr. Hazen here offers in regard to the variation of temperature on Mt. Washington with the passage of a cyclone, contains nothing essentially opposed to my views and the observations in the Alps. With the approach of a whirl the peak has southeasterly and southerly winds, which have a higher temperature than that of the northerly and northwesterly winds in the rear of the storm. On Mt. Washington this contrast must be especially great, since the southerly and southeasterly winds come from the warm Gulf Stream, and the northerly and northwesterly winds from Arctic North America. The notion that the greatest temperature depression may be found in the center

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* Austrian *Met. Zeitschrift*, 1888, p. 13.

† Details will be found in *Amer. Met. Jour.*, Oct. 1887, and *Science*, August 1, 1890. See also Hazen in *Amer. Met. Jour.*, March, 1888, and *Science*, Sept. 5, 1890.

of a cyclone I have shown, contrary to M. Marc Dechevrens, to be an error, sustained neither by observation nor theory. Only in summer cyclones may this sometimes be the case. The great cooling in a summer cyclone is for the larger part an effect of the precipitation from a great height. When, as with the passage of the notable low area of July 12–13, 1890, a heavy snowfall can occur (in the Alps) down at a level of 600 m. (1969 feet), there is the strongest evidence that the condensation-product dropped from a great height can cool the lower layers below their environment by the consequent melting.* One certainly cannot assert in the face of such facts that the air mass in a low area is in contrast to its environment by reason of a relatively high temperature.

"But when Professor Hazen says that on Mt. Washington the temperature in the center of an anticyclone falls and is lower than before and afterward, we venture to doubt, first, because we have once shown already that in anticyclones on Mt. Washington the so-called 'temperature inversion' prevails exactly as with us, and secondly, because meteorological phenomena on Mt. Washington cannot easily prove directly the reverse of those in the Alps, on the Sonnblick and on Pike's Peak." †

BIBLIOGRAPHY OF MEXICAN METEOROLOGY.—Don Rafael Aguilar Santillán has collected into an octavo of 48 pages references to Mexican meteorology to the number of 228. This includes some foreign authors but it is acknowleged by its author to be incomplete. It also includes about thirty references to Mexican volcanoes and earthquakes. The references are arranged under the author's and there is a classified index of the subjects. The last could very properly have been more extended, but the pamphlet forms a very welcome addition to meteorological literature.

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* The low area of July 12, 1890, in the Gulf of Genoa, which on the morning of the 13th was over the Gulf of Fiume and Croatia, deserves careful examination. It caused in both days extraordinary heavy rain and snow on both sides of the Alps. All Alpine rivers rose to a dangerous level in the valleys, an almost unheard-of event near the middle of July. At Innsbruck (600 m.), for instance, the snow fell to a depth of many centimeters, and bent down the rose, wechsel and other bushes. The temperature sank at 400-500 mm. to 4° or 5° C. (39° to 41° F.). This inherently cold air cannot have come from the north, as in North Germany and over the North and Baltic Seas the temperature stood between 12° and 15°. This strange cooling was in part an effect of the north wind, and in part surely an effect of the precipitation (snow) from a great height. On the Obir 2044 m. which lay quite near the center of the low area, there prevailed a temperature of only 4°.2 C. with a SE. wind and heavy rain on the morning of the 13th. This same low, like the attendant thunderstorms of 12-13, were of exceptional interest and extent.

† Dechevrens, *Amer. Met. Jour.*, August, 1886.

TORNADOES IN NEW YORK.

STATE TORNADO CHARTS.—NEW YORK.

By Lieut. Jno. P. Finley, Signal Service, U. S. A.

Table No. I.—*Tornadoes in New York.*

Period of observation, 102 years,—1787–1888.
Total number of storms,—103 storms.
Year of greatest frequency, 1888,—25 storms.
Average yearly frequency,—3.2 storms.
Year in past ten (10) years, no report of storms,—1880 and 1882.
Month of greatest frequency, July,—39 storms.
Day of greatest frequency, July 11th,—9 storms.
Hour of greatest frequency, 3 to 4 P. M. and 4 to 5 P. M.
Months without storms, December.
Prevailing direction of storm movement, NE.
Region of maximum storm frequency, south-west and north-east portions.

TABLE II.—*A Chronological List, showing the location, date and time of occurrence, and general character of formation and movement of Tornadoes in the State of New York for a period of 102 years, from 1787 to 1888.*

State.	County.	Month and Day.	Year.	Time.	Direction.	Form of Cloud.	Width of Path in Feet
New York	Schuyler		1787 or 1788				660
"	Steuben		1791				
"	Cortland	August 13.	1804				
"	Steuben		1808*				
"	Dutchess	September 9.	1821				
"	Franklin	August 21.	1823		SE., then E.		Narrow.
"	Clinton	June 11.	1831				
"	Cayuga	July 20.	1831				
"	Steuben		1833				1,320
"	Cattaraugus, Alleghany and Steuben	March 20.	1834	2 p. m.	E. 20° N.	Funnel.	
"	Oneida	August 14.	1834	4:30 p. m.	E.		5,280
"	Columbia	June 19.	1835	4 p. m.	NE.		495 to 1,320
"	Chautauqua	"Summer."	1835	"Midday."	Easterly.		330
"	Dutchess	June 3.	1837	6 p. m.	E.		1,155 to 5,280
"	Cattaraugus, Alleghany and Steuben	July 25.	1838	1 p. m.	E. 20° S.		3,960 to 5,280
"	Alleghany	July 25.	1838	Afternoon.	SE.	Inverted funn'l	2,800
"	Alleghany	July 13.	1839	About noon.	SE.		25
"	Jefferson	September 20	1845	3 p. m.	E.		2,640 to 7,860
"	Lewis	June 15.	1850	Afternoon.	NE.	Funnel.	Narrow.
"	Cayuga and Cortland	August 13.	1854		ESE.		Narrow.
"	Oneida	June 13.	1857				
"	Oneida	June 13.	1857		SSE.	Inverted Cone	300
"	Oswego	June 13.	1857				
"	Sullivan	September 17.	1857				660
"	Cortland	September 30.	1858		E.		

TABLE II.—*Continued.*

State.	County.	Month and Day.	Year.	Time.	Direction.	Form of Cloud.	Width of Path in Feet
New York.	New York	July 13.	1859				
"	Chemung	July 24.	1859				
"	Cattaraugus	May 30.	1860	3 p. m.	NE.	Funnel.	1,320
"	Cattaraugus and Erie	May 30.	1860	3 p. m.	NE.	Funnel.	
"	Cattaraugus	July 4.	1860	Afternoon.	NE.	Funnel.	
"	Cattaraugus	July 4.	1860	p. m.	NE.	Fuuuel.	
"	Erie	May 9.	1875	p. m.	NE.	Funnel.	800 to 1,000
"	Orange	July 13.	1875	7:10 p. m.	NE.		
"	Albany	August 22.	1875				
"	Erie	February 14.	1876				
"	Washington	March 21.	1876				
"	Ulster	May 22.	1866	Afternoon.			
"	Washington	July 10.	1876				
"	Washington	May 18.	1877	1:30 p. m.			
"	Dutchess	July 1.	1877		SE.		
"	Westchester	July 7.	1877	Afternoon.			
"	Dutchess	July 16.	1877	Afternoon.	NE.		
"	Oneida	July 10.	1878	Noon.	ENE.		
"	Albany	July 21.	1878	1:20 p. m.	E.	Funnel.	
"	Washington	July 26.	1878	5:30 p. m.	NE.	Funnel.	80 to 150
"	Montgomery	August 9.	1878	Afternoon.			100
"	Greene	July 16.	1879	2:30 p. m.			
"	Ulster	July 16.	1879	4 p. m.			
"	Onondaga	July 30.	1879	Afternoon.	NE.		
"	Chemung	September 25.	1881	5 p. m.	SE.		5,280
"	Monroe	October 17.	1881	8:30 p. m.	NE.	Funnel.	
"	Cattaraugus and Wyoming	June —.	1883	5 p. m.	ENE.	Funnel.	

TABLE II.—*Continued.*

State.	County.	Month and Day.	Year.	Time.	Direction.	Form of Cloud.	Width of Path in Feet
New York.	Broome	July 2.	1883	3 p. m	SE.	Funnel.	1,320
"	Monroe	July —.	1883	....	ESE.	Funnel.	1,000
"	Erie	July 3.	1883	Morning.	E.	....	....
"	Schuyler and Tompkins	November 6.	1883	4 p. m.	E.	Funnel.	825
"	Steuben	July 4.	1884	Afternoon.	NE.	....	1,320
"	Alleghany and Steuben	July 5.	1884	11:30 a. m.	NE.	Funnel.	....
"	Steuben	July 5.	1884	11:50 a. m.	NE.	....	....
"	Steuben	July 5.	1884	2 p. m.	NE.	....	500
"	Steuben	July 5.	1884	11:50 a. m.	NE.	Funnel.	....
"	Alleghany	September 28.	1884	6:20 p. m.	NE.	Funnel.	800
"	Alleghany	June 22.	1885	2:20 a. m.	NE.	Funnel.	....
"	Schenectady	July 9.	1885	About 2 p. m	NE.	....	....
"	St. Lawrence	August 12.	1884	4:30 p. m.	NE.	Funnel.	2 640
"	Wyoming	August 16.	1886	3:30 p. m.	NE.	Funnel.	Narrow.
"	Niagara	August 16.	1886	4 p. m.	NE.	Funnel.	....
"	New York and Queens	September 12.	1886	6 p. m.	NE.	Funnel.	....
"	Steuben	May —.	1886	3 p. m.	NE.	Funnel.	2,640
"	Wayne	January 30.	1887	4:20 p. m.	NE.	Funnel.	600
"	Chautauqua and Cattaraugus	January 30.	1887	9 p. m.	NE.	....	....
"	Chemung and Tioga	February 11.	1887	11:30 a. m.	E.	Funnel.	150 to 1,720
"	Chemung	February 11.	1887	11 a. m.	SE.	Funnel.	2,640
"	Monroe	April 15.	1887	5 p. m.	E.	Funnel.	Narrow.
"	Erie	May 7.	1887	1:30 p. m.	NE.	Cone.	1,320 to 2,640
"	Alleghany	June 24.	1887	6:10 a. m.	NE.	Funnel.	Ab'vegr'und
"	New York	July 16.	1887	Noon.	Easterly.	Funnel.	Narrow.
"	Yates	July 17.	1887	6 p. m.	E.	Cone.	2,640

TABLE II.—*Concluded.*

State.	County.	Month and Day.	Year.	Time.	Direction.	Width of Form of Cloud	Width of Path in Feet
New York	Wayne	March 27.	1888	2 a. m.	E.	Globular.	2,640
"	Steuben	May 28.	1888	4:30 p. m.	NE.	Funnel.	2,640
"	Steuben	May 28.	1888	4 p. m.	Easterly.	....	1,320
"	Alleghany	May 28.	1888	5 p. m.	Easterly.	Cone.	2,640
"	Cattaraugus	May 28.	1888	4:20 p. m.	ENE.	Funnel.	1,320 to 2,640
"	Chemung	May 28.	1888	5 p. m.	NE.	Funnel.	500 to 1,200
"	Alleghany	May 28.	1888	4:30 p. m.	E.	Funnel.	Narrow.
"	Oneida	May 28.	1888	5 p. m.	ENE.	Cone.	2,640
"	Washington	June 7.	1888	6 p. m.	NE.	Funnel.	1,320
"	Wayne	June 9.	1888	7 p. m.	ENE.	Funnel.	2,640
"	Cayuga	June 24.	1888	4:30 p. m.	NE.	Funnel.	75 to 100
"	Franklin	July 11.	1888	5:30 p. m.	NE.	Funnel.	Narrow.
"	St. Lawrence	July 11.	1888	5:40 p. m.	NE.	Funnel.	5,000 to 7,000
"	Herkimer	July 11.	1888	5:30 p. m.	NE.	Eunnel.	3,500
"	St. Lawrence	July 11.	1888	6 p. m.	NE.	Funnel.	2,640
"	St. Lawrence	July 11.	1888	6:30 p. m.	NE.	Funnel.	4,000 to 5,000
"	Franklin	July 11.	1888	5:30 p. m.	NE.	Funnel.	2,640
"	Franklin	July 11.	1888	4:45 p. m.	NE.	Funnel.	1,320 to 3,500
"	St. Lawrence	July 11.	1888	6 p. m.	NE.	Funnel.	2,640
"	St. Lawrence	July 11.	1888	5:30 p. m.	NE	Funnel.	3,000
"	Wayne and Cayuga	August 8.	1888	4:30 p. m	NE.	Funnel.	60 to 100
"	Cayuga	August 8.	1888	3 p. m.	NE.	Funnel.	600
"	Wayne	August 8.	1888	4 p. m.	NE.	Eunnel.	500 to 840
"	Niagara	August 16.	1888	7:30 p. m.	NE.	Funnel.	500 to 1,200
"	Erie	September 27.	1888	6:30 p. m.	NE.	Funnel.	1,320 to 2,000

TABLE III.—*Relative frequency of Tornadoes by months and days, for New York.*

The index figures to the right and above the dates show how many times tornadoes occurred on that day of the month.

Month.	Day of Month.	No. of Days.	Total No. of Tornadoes per month.
January	$(30)^{2}$	1	2
February	$(11)^{2}$ and 14	2	3
March	20, 21 and 27	3	3
April	15	1	1
May	7, 9, 18, 22, $(28)^{7}$, $(30)^{2}$ and (—)	6	14
June	3, 7, 9, 11, $(13)^{3}$, 15, 19, 22, $(24)^{2}$ and (—)	8	13
July	1, 2, 3, $(4)^{3}$, $(5)^{4}$, 7, 9, $(10)^{2}$, $(11)^{9}$, $(13)^{3}$, $(16)^{4}$, 17, 20, 21, 24, $(25)^{2}$, 26, 30 and (—)	18	39
August	$(8)^{3}$, 9, 12, $(13)^{2}$, 14, $(16)^{3}$, 21 and 22	8	13
September	9, 12, 17, 20, 25, 27, 28 and 30	8	8
October	17	1	1
November	5, 6	1	1
——	(—), 8	—	5
Total		57	103

NOTE.—The blank signifies date missing.

CURRENT NOTES.

REVIEW OF THE WORK OF THE PILOT CHART.*—With this number the eighth year of this publication begins, the first number having appeared in December, 1883. The various changes and improvements that have been made in the Chart since that time are strikingly shown by a comparison between a late copy and that first issued. The most conspicuous additions are the following: Steam and sailing routes; region of equatorial rains; table of barometer normals and percentage of probable calms for each 5° square; storm diagrams, with brief rules for action to avoid a hurricane; cautionary and storm signals in use along the Atlantic and Gulf coasts of the United States; the tracks, names and dates of derelicts; list of dangerous obstructions to navigation along the coast, and of charts published and canceled during the preceding month; regions of observed and predicted fog. Besides these additions, and other less striking ones, the greater portion of the forecast meteorologic data have been thoroughly revised and brought up to date, while the review is prepared with very much greater accuracy and completeness, owing to the far greater number of observers who now send in regular reports and the hearty approbation and support received from masters of vessels of every nationality.

During the last three years especial efforts have been made to publish promptly and make practically useful to navigators the results of the many reports that are made to this office, thus giving to each and every observer the benefit of the combined experience of hundreds of observers, and at the same time securing a wide and international circulation for data relating to the ocean. In this attempt two objects have been kept in view: first, to give, in clear, practical form, as much late and important news as possible to navigators, and to aid them by every means in our power in lessening the dangers of the sea and increasing the safety and success of commerce; secondly, to attract the interest and attention of other classes of people to the life and duties of the officers and men of the navy and mercantile marine, and thus to insure a fair hearing and some attention and sympathy in any reasonable effort to improve the status and prospects of sea-faring men and others directly interested in commerce. That these efforts have been successful to some extent seems to be indicated by the support that our work has

* From the Pilot Chart of the North Atlantic Ocean, December, 1890.

received from masters, owners and agents, as well as from the public generally, and numerous quotations might be made from home and foreign reviews, and from public and private statements by recognized authorities, showing general recognition of the fact that this publication has achieved success in a new and untried field, and has been creditable to the United States. Not the least of the valuable results that have been achieved is the general recognition of the benefits to be derived from the use of oil in preventing heavy seas from breaking on board vessels, a result universally attributed to the reports that have been published on this Chart.

The subject of derelicts at sea, and the danger therefrom to commerce, has been emphasized in the same way, and some authorities are of the opinion that the recent Marine Conference owed its inception largely to the interest caused by the continued publication of such data.

A feature of the Pilot Chart that deserves special mention is the occasional publication of a Supplement devoted to some subject of immediate importance. This plan was first tried in September, 1887, and since that time several supplements have been issued, each of which has attracted much favorable attention, and has been widely quoted. The following is a complete list of those published thus far:

September, 1887.—West Indian Hurricanes. Diagrams and text explaining the circulation of the wind in a hurricane, with brief rules for action.

December, 1887.—Trans-Atlantic Steamship Routes for December. The plan for steamer-routes recommended in order to avoid collisions, with a brief discussion of the winter storm-belt of the North Atlantic.

March, 1888.—Waterspouts off the Atlantic Coast of the United States during January and February, 1888. Positions of waterspouts plotted on a small chart, with reports quoted in full and a discussion of the subject.

August, 1888.—Derelicts and Wreckage in the North Atlantic. A history of the great log-raft, with a complete list of reports received from vessels that sighted the logs as they spread over the ocean, together with a graphic record of the drifts of the most notable derelicts.

February, 1889.—The Derelict American Schooner, W. L. White. An account of the trans-atlantic voyage of this notable derelict vessel, with all reports received and a chart showing the

track of the vessel and the general drift of Atlantic currents.

October, 1889.—The St. Thomas-Hatteras Hurricane of September 3-12, 1889. Ten small charts, with accompanying text, illustrating the progress of this great hurricane from St. Thomas to our coast north of Hatteras, with a complete list of vessels from which reports were received in time for use in this connection.

During 1890 no supplements have been issued, but a large number of reprints, in black and white, have been made of the various diagrams and printed matter accompanying the Chart. These have been widely circulated and republished, notably by the New York *Herald*, the Boston *Post*, and the Liverpool *Journal of Commerce*, to which papers this office is especially indebted for valuable assistance and support.

It is proposed to publish with the January Chart a supplement devoted to the subject of ice in the North Atlantic during the season of 1889-'90. This will contain charts showing the positions and dates of icebergs and field-ice reported during the past season (perhaps the most notable ice season on record), for which the data at hand are very complete. Full credit will be given for every report received, and quotations will be published from reports containing information of special value.

A Civilian Directorship of the New Weather Bureau.—In this octavo pamphlet of twenty-four pages, Mr. Thomas G. Brown, of Washington, makes a strong plea in favor of civilian direction for the new Weather Service. There are many facts mentioned which have escaped the attention of meteorologists outside of Washington and the paper is of interest as a contribution to the history of meteorology in this country. The pamphlet seems to be a private publication, but we presume it can be obtained by applying to its author at 636 Massachusetts Ave., N. E., Washington, D. C.

Exhibition of Rain and Evaporation Gauges.—The Royal Meteorological Society's twelfth annual Exhibition of Instruments was opened on the third of March in the rooms of the Institution of Civil Engineers, 25 Great George Street, Westminster. The exhibition this year was devoted to Rain and Evaporation Gauges, and such new instruments as have been constructed since the last exhibition.

Almost every known pattern of rain-gauge that has been used

in this country was shown, and it was interesting to compare the old patterns with the new patterns. Most of the gauges had funnels five or eight inches in diameter. The Meteorological Office eight-inch gauge is generally regarded as the best gauge for ordinary observers to whom cost is not a primary object, as it has all the good features of the Glaisher and of the Snowdon patterns, and, being of copper, is very durable. In mountainous districts, where the rainfall is heavy, and the gauges can only be periodically examined, those capable of holding 40 or 50 inches of rain must be used. Specimens of these gauges, as well as of the rain and snow-gauge used in France, Germany, Russia, Switzerland, and the United States, were shown in the exhibition. Some interesting storm-gauges and self-recording-gauges were also exhibited. The evaporation gauges included several instruments employed for measuring the evaporation from a free surface of water, and others for use with growing plants. A number of new instruments were also exhibited, among which were various anemometers, recording barometers, and cameras for meteorological photography. An interesting collection of maps of rainfall over the British Isles and various parts of the world, as well as numerous photographs of floods, meteorological phenomena, etc., were also on view. The exhibition remained open till the 19th.

THE RIO GRANDE.—The waters of this river, in New Mexico and Upper Texas, are derived from three sources, viz.: the snow on the New Mexican mountains, that on the lower ranges of Southern Colorado, and that on the higher Coloradan ranges. By far the largest part of the snow is in the complex of mountains which extends over into New Mexico from Southern Colorado, and it often lies here to very great depths. It is, perhaps, the most noteworthy center of heavy snowfall in the United States. When the snow on the New Mexican and Coloradan mountains is successively melted there is moderate high water and prosperity. The melting of the snow on the high ranges never comes until after that on the low, and it is this that furnishes most of the water for irrigation. When the melting of the snow on the low ranges occurs rapidly and together, there are floods on the Rio Grande. Such floods occurred in 1884, when damage was done about and below Los Lunes, and very serious damage about Las Cruces. There is little probability of a flood in the spring of 1891.

DR. WINCHELL AND DR. CROLL.—Dr. Croll died on the 15th of January and Dr. Winchell on the 19th of February of this year. They were both geologists who paid much attention to climatic problems. Dr. Winchell's published climatic results related, for the most part, to Michigan. He made a special study of the influence of the lake region on the isothermals and printed his results in the *Proceedings of the American Association for the Advancement of Science* for 1871. They were afterwards often reprinted and were translated in the *Austrian Journal*. He also called attention to the Grand Traverse region of the State and the pamphlet, printed in 1866, devoted to the climate and soils of that region was of great service to it. He has also published a paper on the fruit-bearing belt of Michigan, (*Proc. Amer. Assoc.* 1866).

Dr. Croll's publications were on the great problems of geological climate. The first paper on this subject appeared in 1864 and at once arrested the attention of physicists and geologists. His greatest and most popular work was "Climate and Time," which appeared in 1875. This gave rise to much discussion and his controversial papers appeared in 1885 as "Climate and Cosmology," making the latter a supplement to the first book. His later publications were devoted to other aspects of astronomical geology.

CLIMATOLOGY OF ALABAMA.—Bulletin No. 18, New Series, of the Agric. Experiment Station of the Agric. and Mech. College at Auburn, Ala., is an octavo pamphlet of 73 pages, and is devoted to the climatology of the state. It gives the tables of monthly means for all years available and illustrates the progress of the elements by graphic diagrams. It also gives details concerning remarkable phenomena. On page 71 are given the mean soil temperatures for Auburn for a series of depths down to eight feet, and for a hill and a valley station. The other state services could do a very useful labor by occasionally summing up their results in this way.

CUMULUS CLOUDS OVER ISLANDS.—While on the south shore of Cape Cod, Mass., last summer, I noticed on several occasions that a group of cumulus clouds formed over a certain point on the southern horizon, in the direction of the island of Nantucket, some thirty miles distant. At such times, the sky over the sun was generally clear, but over the land to the northwest,

there were numerous fair weather cumuli; and the curved outline of Cape Cod itself could sometimes be traced in the sky by the clouds that seemed to form over it. The Nantucket and Cape clouds, as I came to call them, did not stand still, but drifted along with the prevailing gentle, westerly summer wind, forming and dissolving as they went. On the 8th of August, the Nantucket cloud group was particularly well developed, and by taking measures of its angular altitude and determining its distance from a map, the height of the base of the cloud was found to be 2400-2500, and of the top, 4000-5000 feet. On writing to the observer of the Signal Service at Nantucket for information about these clouds, he replied as follows: "We have no record of clouds for noon of the 8th, but an assistant at this station states that he observed a group of two-tenths cumulus clouds lying stationary in a northeasterly direction from the place on the date and hour mentioned, being doubtless the same group seen by you. This was an ordinary occurrence and called for no especial note on our part. . . ." I infer from this reply, coupled with my own observations, that the local formation of cumuli over Nantucket is characteristic of the quiet warm summer days, just as it is almost every day in the year over certain tropical islands. W. M. D.

CORRESPONDENCE.

RAINS IN THE STATES.

To THE EDITORS: The following observations may possess some practical value. The positive case is adopted to save words.

Rains, over central regions in this country, fall almost exclusively from direct importations of vapor in bodies of air carried inland from over the Atlantic ocean and southern gulf.

Largely the evaporation from the face of the land is carried out over the eastern seaboard, during spells of fair weather, in the general easterly movement of the lower atmosphere. Very little available moisture is from the west, as the elevation of the mountains condenses the greater portion on their western slopes.

Two great typical cases of importation may be cited in support of this theory and for special scrutiny:

One a high centre well north, on or near the eastern coast, when the immense sweep of the right-handed movement in the

southern half of the meteor brushes across the waters of the ocean, carrying inland vast supplies of vapor. Almost invariably rains begin in the southeast, spread rapidly west and north, are persistent, wide-spread and frequently heavy under this arrangement.

The second involves moderate pressures east and west and the occupation of the Mississippi valley by a large low area when immense volumes of vapor are brought from over the gulf by the northerly movement in the eastern half of the rotating mass, in which case rains originate in Texas and spread rapidly north and east. Observation will disclose every possible combination and variation of these two cases. It is frequently possible to observe and trace the advancing edge of the vapor mass by the spread of the rains.

The increasing elevation of the land and the layer of air held to it against the general movement by friction plays an important part in subsequent results by lifting the warm, moist air from the gulf or ocean to a considerably greater elevation than that at which it starts. Also the mass loses heat by radiation to the cooler earth below and into space above.

For the last two months the rains have been distinctively under the former of the two cases and none of the movements have persisted long enough to produce heavy precipitation as far inland as Ohio.

The influence of radiation from the top of clouds into space, in producing precipitation, appears to be very greatly underestimated. What it amounts to is in some degree measurable from the consideration that as much heat radiates from the earth in 24 hours as is received from the sun in 12. This loss is increased from the upper surfaces of clouds by the elevation at which they are exposed, above a large portion of the atmosphere, with a temperature above the normal for the elevation, and by the immense surface exposed by minute drops.

ORIN PARKER.

COLUMBUS, O., Dec. 22, 1890.

LIGHTNING AND TELEPHONE POLES.

TO THE EDITORS: An opportunity was afforded this summer to observe the effects of lightning upon twenty telephone poles; the line of observation being about one mile in length.

The road extended north and south. Commencing at the

northern end of this line, five poles were struck. They may be numbered 1, 2, 3, 6, 12. Then followed thirty-two poles that were not touched. The next that were struck were numbers 45, 46, 48, 50, 51, 52, 53, 54, 55, 56, 57, 58, 59, 61, 62.

It was noted that, in most cases, the wood was shaved from the top to the bottom of the pole in the form of a spiral, *turning opposite to the watch hands.* This occurred in fourteen cases. In five others it went straight from top to bottom. Once it turned with the watch hands. Four times it made one-fourth of a complete turn; once it made one-third; four times one-half, and four times three-fourths of a complete turn. In the one case where it turned to the right it made one-eighth of a complete turn.

The width of the track of the flash was from .026 to .044 meters, with one exception, where it was .108 meters. The grooves were about one centimeter deep, with edges beveled toward the median line at an angle of about 30. The bottom of each groove was for the most part perfectly smooth and flat, or slightly concave outward.

The direction of the spirals was significant, and closer examination revealed the fact that in every instance the flash followed the direction of the grain of the wood, as shown by its being parallel to the weather beaten cracks in the wood.

It is not known whether the damage was done by one flash or more. H. P. NOTTAGE, M. D.

Westport, Mass., March, 1891.

SUN SPOT AND OTHER PREDICTIONS.

TO THE EDITORS: To establish the fallacy of sun-spot weather predictions requires merely a superficial consideration of the relations of the sun to the earth. The sun, from whence we receive light and heat, is about 1,000,000 times larger than the earth, and we are distant more than 90,000,000 miles from that luminary. The earth is an inconsiderable particle in the solar system. Attempts have been made, presumably in good faith, to prove that solar disturbances affect the weather conditions, not of the earth as a whole, but the comparatively infinitesimal parts thereof called states or parts of states. The sun-spot theorist will account for a spell of abnormally warm weather in New York or New England on the ground of sun disturbances while during the same period unusually cool weather will pre-

vail in Michigan or some other limited area in the central or west part of the country. It is a well known fact that even within the limits of the United States abnormally warm or wet spells in one section are almost invariably attended by the reverse of these conditions in another section. Is it possible that solar disturbances can produce excesses of heat or moisture in such small areas, or, granted that heat may be focused at one point by these disturbances, can they produce opposite results in such a limited règion? It has been claimed that protracted solar disturbances occasion abnormally warm, wet, or stormy seasons, as the case may be, and yet in the case of seasonal excesses over considerable areas of the earth's surface the opposite of these conditions invariably occurs over other parts of the earth. Can the earth be affected in a diverse manner in spots by a sudden accumulation of heat by the sun? As an illustration of theories relating to the interruption or augmentation of heat from the sun as affecting the earth the following may be related: During the Turko-Russian war the early part of the winter was unusually warm in New York state. A local meteorologist advanced the statement that the warm weather was due to the arrival at the earth of heat from the sun that had been intercepted and delayed by an eclipse that had occurred some time before. The newspapers were at this time reciting how severe the weather was at the seat of war in southern Europe. Terrific snow storms and intense cold of unprecedented severity prevailed. I called the local meteorologists attention to the fact and asked him how he could account for the fact that the delayed heat he referred to had not reached that part of the globe. His only reply was that he had not thought of that. It may be stated with equal fidelity to facts that in the present stage of meteorological knowledge all predictions, save those based upon existing meteorological conditions, whether local or defined by plotted telegraphic reports, are devoid of thought. The popular and ancient predictions based upon the thickness of corn husks, etc., are absurd when subjected to a moment's thought. The growth of all vegetation is necessarily dependent upon the conditions of heat and cold, dryness and moisture during the growing season. The instincts of animals form another base of operations. These instincts are necessarily limited to existing conditions. Their senses are ofttimes very acute, enabling them to recognize atmospheric changes in advance of man, but they have no knowledge, no thought even,

of the future. In fur bearing animals the thickness of the fur is cited as an index of the character of the succeeding winter, while as a matter of fact the fur is dependent upon the condition of the animal, and his condition upon the character of his food, and that upon the weather that has past, as being favorable or unfavorable to the growth and maintenance of vegetable or animal life upon which he is wont to subsist.

Statements based upon averages of preceding years indicate merely the averages or means for the days or periods designated, and cannot be classed as forecasts. Investigating meteorologists who endeavor to define weather cycles find the recurring periods only to lose them. The general laws of nature are mathematically exact, and it is within the possibilities that a systematic study of the enormous mass of data collected by the Weather Bureau may lead to the discovery of laws governing the periodic occurrence of certain meteorological conditions.

E. B. Garriott.

Washington, D. C., December 26, 1890.

BOOK NOTICES.

TORNADOES AND THEIR THEORIES.*

This little book covers not only the facts and theories of tornadoes but also some practical sides of the questions of tornado losses, insurance, prediction and observation. There is also considerable space devoted to such supplementary subjects as Espy's experiments, sun-spots and thunder-storms. The whole is given in the incisive manner familiar to those who have read the previous articles of the author on this and allied subjects. The book may be looked on as an enlargement of the author's prize essay published in the Journal and as a substantial reproduction of a later series of articles in *Science;* in fact this appears to be an exact reprint of the latter.

There is much to admire in the industry shown in the collection of facts and the keenness in separating the facts from all sorts of fiction. The conscientiousness of the author and his vigorous independence cannot be doubted for a moment, and

* "Fact and Theory Papers; The Tornado." Professor H. A. Hazen. New York, 1890. Duodecimo, 147 pages.

these always give a charm to any book, and especially so, when, as is the case here, the writer is thoroughly well read in his subject. Yet, while recommending every one interested in the subject to read this book, we cannot commend it without two qualifications. One is due to the fact that Professor Hazen's freedom from bias is so strong that it is positive rather than neutral. He is like the man who stood up so very straight that he leaned over backwards. Professor Hazen does not give enough credit to the labors of the students of the subject, neither few nor insignificant, who have preceded him. The demonstrated and accepted constants of physics, on which such writers as Reye and Ferrel based their deductions, seem to be questioned, while the strict mathematical deductions used by some of them are not even mentioned. Surely for such men it is not true, as stated on p. 37, that they "have contented themselves with the assumptions and necessarily crude results obtained by the first experimenter" (Espy). Such structures as have been raised by these men and by others, like Faye, cannot be destroyed without a more careful and critical treatment than we find in this book.

In place of these recognized laws and forces, the author seems content to substitute some which are very uncertain. For the recognized and definite principles of aero- and thermodynamics used by his predecessors, he is satisfied to vaguely appeal to unknown properties of electricity. It is an appeal from the known to the unknown, or even worse than this, for Dr. Mendenhall has recently reported that careful investigation has failed to show any demonstrable relation between weather and atmospheric electricity. This is the second general objection which we have to this book. It would not perhaps be fair to say that the author sets up a definite electrical theory for tornadoes. He seems rather to have found the present theories unsatisfactory and to have simply suggested that there were indications that electricity played an important part. But this, we think, in a popular book of this sort, is open to very serious objections.

THE SOLAR SYSTEM AS A MOLECULE.

Some poet or poetical philosopher has imagined, half in jest, as we remember it, that the universe itself is a solid of which the individual systems, like the solar, are the molecules, and

that there may be giants who walk over this solid using perhaps a handful of stellar systems for a snowball. There is nothing in Mr. McLennan's attractive-looking book * which goes to this extreme; at the same time the author really does attempt to show that the solar system has a structure analogous to a common interpretation of that of the molecule,—and he has apparently found the analogy complete. Just as the atoms have bonds to connect them, so he gives the sun and planets bonds, slender, ethereal, elastic, like a fluid india-rubber, to connect them. By means of these bonds they are held in their places, receive light and heat, act toward each other as if there were a force like gravitation between them and, in general, receive and expend energy exactly as if there were present the universal ether generally accepted. Moreover by the addition of the ethereal matter about the earth when the bonds shorten because of decrease of distance, or by addition of bonds of other planets when the latter are in opposition, the various phenomena of precipitation and atmospheric electricity may be explained and predicted, and the bonds themselves may be imperfectly seen in the corona and zodiacal light All this is worked out in much detail and the whole shows extensive reading and much acuteness.

We fear, however, that Mr. McLennan's ingenious theory will not meet with general acceptance, partly because the leaders in science seem to be fairly satisfied with the present theories, faith in which generally grows with knowledge, and partly because the theory of bonds suffers under several fundamental objections. In the first place, the attractive analogy to a molecule, —attractive because it appears to show a fundamental identity of arrangement in the very great and very small,—fails entirely on a closer examination. The chemist himself does not seem to believe in objective material bonds, he only gives that name to a capacity for combination the exact nature of which he does not attempt to define, but which is much more likely to be a result of form or of nodes of vibration than to anything of the nature of india-rubber strings. Moreover, in chemistry the number of bonds is limited,—the valency is definite—while with the molecule made up as the solar system the number of bonds is unlimited, or the valency is indefinite.

* "Cosmical Evolution: A New Theory of the Mechanism of Nature." By Evan McLennan. Octavo, 422 pages. Chicago, 1890.

In reading his book, we could not but wonder what arrangements the author had made for matter in small masses, scattered through the system. The secondary bodies of the system controlled by the sun, vary all the way from Jupiter to no one knows the lower limit; it may be that of a mustard seed, or that of a starch grain, or that of a solitary molecule, very likely the last. All the space through which we pass is thickly populated with these bodies; the earth sweeps up many thousands of them every day. Does each have its bond? If so, all the bonds together would nearly make up a continuous ether. Then, also, as attraction can act only along this bond, why is a meteorite, with a solar bond, attracted to the earth or to Jupiter, or if it has a bond to each why do not some of its bonds break by tension, or get cut by intersection by some other meteorite? How does the particle sent off from a comet behave? Is it attracted only by the comet from which it would derive its original bond? If by the sun or any other body how did it get its bond to that? In short, if each molecule is bound by bonds to every other molecule in the universe, and this appears a necessary outcome of Mr. McLennan's theory, then all these bonds taken together will make a fairly continuous ether, and he agrees with all competent authorities.

ERRATUM.—In the table on page 490, the column "Indicated Velocity" should read, 0, 10, 20, 30, etc.

PUBLICATIONS RECEIVED: WEATHER SERVICES AND OBSERVATORIES FOR 1890.

I.—DOMESTIC.

"Monthly Weather Review: General Weather Service of the United States." Washington. Edited by different officers, usually Captain Dunwoody. Quarto, twenty or more pages, three maps. Besides the usual summaries of observations and abstracts of special phenomena, it has contained, during the past year, many reports of monthly temperatures and precipitation, for long series of years, from many stations.

"Pilot Chart of the North Atlantic Ocean." Published monthly at the Hydrographic Office, Navy Department, Washington, Lieut. Richard Clover, acting hydrographer. Gives meteorological data concerning the North Atlantic, including the paths of centers of low pressure; also often some study of interest, as on the use of oil at sea, or on the following, with special

charts: Hurricane of November 25, 1888 (June chart); Typical circulations of wind in North Atlantic hurricanes (July chart); Great hurricane of August, 1887 (August chart); Surface temperature in August (September chart); Hurricane of August 27, 1890 (October chart); Drift of bottle-papers in the North Atlantic (November chart). The charts present a surprising amount of information, presented in a graphic form.

"Magnetic Observations at the United States Naval Observatory, 1888 and 1889: Washington Observations, 1886, Appendix I." Capt. F. V. McNair, U. S. Navy, superintendent; Ensign J. A. Hoogewerff, U. S. Navy, in charge of magnetic observations. Bound, quarto, 100 pages and fourteen sheets of tracings. This magnetic observatory has been but recently established; it has a full complement of instruments, and the observations and reductions are made with the care needed for an institution of the first class.

"Bulletin of the New England Meteorological Society in Coöperation with the Astronomical Observatory of Harvard College and the U. S. Signal Service." Monthly, large octavo, eight pages. Cambridge, Professor W. M. Davis, editor; 258 stations.

"Summary of Observations of the Leicester Academy Meteorological Observatory," Leicester, Mass., Mr. Arthur Kendrick, observer. Monthly, octavo, four pages, manuscript. January and February only received.

"Summary of Observations; Blue Hill Meteorological Observatory." Monthly, octavo, four pages. Mr. A. Lawrence Rotch, proprietor; H. H. Clayton, observer; S. P. Fergusson, assistant. Record for January only. The Harvard College Observatory now publishes the observations.

"Report of the New York Meteorological Bureau," Cornell University, Ithica, N. Y., Professor E. A. Fuertes, director. Monthly, quarto, eight to twelve pages, with map of isotherms and one of rainfall. May, and July to November received.

"Monthly Summary of the New York Meteorological Observatory," Central Park, New York City, Dr. D. Draper, director. Large octavo, eight pages.

"Monthly Weather Review of the Pennsylvania Weather Service." Prepared under the direction of the Committee on Meteorology of the Franklin Institute. Monthly, octavo, eight pages, and temperature and rainfall chart. Thirty-one stations.

"North Carolina Agricultural Experiment Station; Meteoro-

logical Division," Raleigh, N. C., C. F. von Herrmann, U. S. Signal Corps, meteorologist. Bulletin No. 73b is devoted to a summary for October and November, 1890, and to an article by the meteorologist on cold waves. Octavo, thirty-six pages, with isothermal and precipitation charts for each month.

"Report of the Alabama Weather Service, Coöperating with the U. S. Signal Service." Auburn, Professor P. H. Mell, director. Monthly, octavo, four pages. This service also publishes a weekly crop report during the season.

"Monthly Bulletins of the Mississippi Weather Service." University, Miss., Prof. R. B. Fulton, director. Octavo, four pages.

"Tennessee State Board of Health Bulletin," Nashville, J. D. Plunkett, M. D., director; Maj. H. C. Bate, assistant. Monthly, octavo, sixteen pages, five or six devoted to the meteorological report.

"Report of the Ohio Meteorological Bureau", Columbus. Professor B. F. Thomas, president; C. E. Kilbourne, secretary; monthly, octavo, about ninety pages, with an annual report which for 1889 contained 218 pages. It also prints a single manuscript sheet bulletin which appears more promptly than the above.

"Michigan Crop Report and Monthly Report of the Michigan Weather Service." Published by the Secretary of State, Lansing; Sergeant N. B. Conger, director. Octavo, twenty-eight pages, three charts. A daily weather map is issued from Detroit, and a weekly crop report during the season.

"The Indiana Weather Service, under the Auspices of the Agricultural Experiment Station at Purdue University, with the co-operation of the U. S. Signal Service, Lafayette, Ind. Professor H. A. Huston, director; Sergeant C. F. R. Wappenhans, assistant. Monthly, octavo, twelve pages. Only October and December have come to hand.

"Monthly Bulletin of the Wisconsin Weather and Crop Service", Milwaukee. Robert E. Kerkam, U. S. Signal Corps, director. Manuscript, four pages. This publication began in October, 1890.

"Publications of the Washburn Observatory of the University of Wisconsin, Vol. VII, Part 1: Meteoro—logical observations." Prof. G. C. Comstock, director, Madison. Large octavo, 87 pages. Contains the observations for 1887–89.

"Monthly Review of the Iowa Weather and Crop Service,

Co-operating with the U. S. Signal Service", Des Moines. Mr. J. R. Sage, director; Geo. M. Chappell, Signal Service, assistant. Quarto, twelve or more pages. This publication began with April, 1890, and contains articles of popular interest along with the official reports.

"Missouri Weather Service", Washington University, St. Louis. Professor F. E. Nipher, director. Octavo, four pages, with rainfall map. From a circular dated February 9, 1891, we learn that this service has been turned over to the State Board of Agriculture. Prof. Nipher has been its director since December 1, 1877.

"Report of the Kansas State Board of Agriculture", Topeka. Mr. M. Mohler, secretary. Monthly, octavo; sixteen pages devoted to meteorological reports. These are also printed in a "Kansas Crop and Weather Bulletin" (of which we have a copy for May, 1890), and also an annual summary in the "Transactions of the Kansas Academy of Sciences". The Service also prints a manuscript weekly crop report in the season. Professor J. T. Lovewell is director of the service, and Mr. T. B. Jennings, U. S. Signal Corps, assistant.

"Weather Bulletin and Crop Report of the Nebraska Weather service, Co-operating with the U. S. Signal Service". Boswell Observatory, Doane College; Professor G. D. Swezey, director, G. A. Loveland, assistant. Monthly octavo, four pages, and rainfall chart.

"Monthly Bulletin of the Texas Weather Service, published by the Galveston Cotton Exchange in Co-operation with the U. S. Weather Bureau". Galveston, Mr. D. Bryan, director, Dr. I. M. M. Cline, U. S. Weather Bureau, assistant director. Quarto, four pages. We have seen only the numbers for November and December, 1890, being Nos. 5 and 6 of volume III.

"Monthly Weather Review of the Nevada State Weather Service, in Co-operation with the U. S. Signal Service". Carson City; Chas. W. Friend, director, H. E. Wilkinson, Signal Service, assistant. Quarto, four pages, tables, precipitation map, and diagrams. An annual report is also published; that for 1889 was an octavo of thirty pages.

"Weather Review; Division of the Pacific". San Francisco, Lieut. Jno. P. Finley in charge. Single type-written sheet. The percentages of verification are unusually high.

"Monthly Report of the Oregon State Weather Bureau in Co-operation with the U. S. Signal Service". Printed by the state

at Salem; Central Office, Portland; Mr. H. Hayes, director; R. S. Pague, Signal Service, assistant director. Quarto, fifteen pages; contains also articles of general interest. October and November numbers only. Also, "Biennial Report of the Oregon Weather Service, Co-operating with the U. S. Signal Service". Printed by the State. Octavo, seventy-eight pages. This is the best compendium of Oregon climate that we have yet seen.

II.—Foreign.

"Monthly Weather Review; Meteorological Service, Dominion of Canada". Toronto, Charles Carpmael, Esq., director. Small quarto, twelve pages. This always includes an abstract of magnetic observations at Toronto.

"McGill College Observatory, Monthly Abstract of Observations". Montreal, Canada, Professor C. H. McLeod, superintendent. Single sheet.

"Boletin mensual; Observatorio Meteorológico-magnético central de México". Mariana Barcena, director. Quarto. The numbers received bring the reports up to the end of 1889 and complete volume two, consisting of 328 pages. It is largely meteorological, but many other subjects, of astronomical, geographical, and agricultural interest, are discussed.

"Observatorio meteorológico del Colegio del Estado de Puebla". Puebla, Mexico; Professor B. G. González, director. Monthly, quarto, four pages.

"Anales del Instituto Fisico-Geographico Nacional; Secretaria de Instruccion de la Republica de Costa Ricca". 1888, Tomo II, Parte, 1, San José. Professor Enrique Pittier. Quarto. The meterological part includes 156 pages, and gives the observations at San José as a station of the first order.

"Observaciones magnéticas y meteorológicas del Real Colegio de Belen de la Compañía de Jesus en la Habana". Rev. Fr. Benito Viñes, director. The latest number is that for the semester January-June, 1888. It is a quarto, and gives both the numerical and graphical data for the meteorological and magnetic elements. Fr. Viñes still continues his studies of the magnetic relations of storms.

"Revista do Observatorio: Publicacao mensal do Observatorio do Rio de Janeiro." Monthly, octavo, sixteen pages. It contains an abstract of the Brazilian observations.

"Annual report of the Meteorological Council of the Royal Society for the year ending 31st of March, 1890."

London, octavo, 147 pages. This council controls the weather forecasts and marine weather service of Great Britain. The members of the council were Gen. Strachey, Dr. Buchan, Professor Geo. Darwin, Mr. Galton, Mr. Stone, and Capt. Wharton. The secretary is Mr. R. H. Scott, the marine superintendent, Lieut. C. W. Baillie. The cost of the service for the year was about $76,000, an increase of about $1,000 over the year before; $8,000 of this was expended for telegraphic service.

"Summary of a Meteorological Journal kept by C. Leeson Prince, F. R. A. S., etc., at his observatory at Crowborough, Sussex," 1889. Large octavo, six pages.

"Annuaire de l'Observatoire municipal de Montsouris pour l'an 1890," Paris, M. Marié-Davy, director. 32 mo, 472 pages. This publication is devoted to Meteorology, Chemistry and Micrography, more especially in their relations to Hygiene.

"Beobachtungen der meteorologischen Stationen im Königreich Bayern, unter Berücksichtigung der Gewittererscheinungen im Königreich Württemberg, Grossherzogethum Baden und in den Hohenzollernschen Länden, herausgegeben von der königlichen meteorologischen Central-Station," Dr. Carl Lang, director, Dr. Fritz Erk, adjunct. Quarterly: quarto, eighteen pages, with a large annual volume which includes some discussion of the observations. This service also publishes a monthly abstract.

"Yahresbericht über die Beobachtungsergebnisse der forstmeteorologischen Stationen." 1889, 15th year. Prof. Dr. A. Muttrich, director. Annual. Octavo, 123 pages. This contains the monthly means from the forest stations of the German Empire.

"Jahrbuch der Wetterwarte der *Magdeburgischen Zeitung,*" A. W. Grützmacher, director, Vol. VII, 1889, quarto, fifty-four

"Bollettino meteorologico; R. Osservatorio di Palermo." Sr. A. Riccó, director, monthly, quarto, four pages.

"Il Rosario e la nuova Pompei." Monthly, octavo, forty-eight pages. Contains reports from the observatory in the valley of Pompeii.

"Annalen des Physikalischen Central-Observatoriums," 1889; Dr. H. Wild; St. Petersburg; quarto, 403 pages. Contains the meteorological and magnetic observations for stations of the first order and exceptional observations at stations of the second and third orders.